MATERIAL MANAGEMENT OF MEDICAL-SURGICAL ITEMS AT MILITARY HEALTHCARE FACILITIES

GRADUATE RESEARCH PROJECT

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Abstract

This research examined whether certain military healthcare facility characteristics could be used as determinants in setting materials management policies. Cost efficiency in the military healthcare system is as important as it is in the civil sector, which has led to an increased emphasis on material management policies and a drive toward stockless inventory practices. The benefits (success) of stockless inventory policies in the civil sector have been mixed. In the early to mid 90's, stockless inventory systems were the end-all solution. They have since faded with many organizations settling on a blend of stockless and traditional inventory practices. Air Force healthcare facilities currently use a Days of Stock inventory policy with defaults set for operating level and safety levels based on source of supply. The material management policies at Air Force healthcare facilities are relatively static with a one-size-fits-all approach, although they vary by size and operation. This study examined the total relevant inventory costs of the (Q,s), (s,S), and stockless inventory policies available in the Defense Supply Center-Philadelphia Medical-Surgical Prime Vendor contract in use at Air Force healthcare facilities located within the continental United States. Further, quantitative approaches analyzed current and past acquisition data to draw conclusions on the best cost minimizing inventory policy based on factors such as number of personnel, number of beds, number of bed days, relative value units, relative weighted products, admissions, and enrolled population. The results show that workload factors such as relative value units and relative weighted products can be used to predict an appropriate least cost inventory policy for individual healthcare facilities.

Dedication

To my wife and children who sacrificed nights and weekends so that this effort could be completed.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Lt Col Pam Donovan. Without her guidance, direction and statistics reviews, this research effort would not be possible. I would, also, like to thank my sponsor, the Medical Logistics division of the Air Force Medical Operations Agency at Ft Detrick, Maryland for both the support and latitude provided to me in this endeavor.

Special thanks goes to Dan Planck at Wright-Patterson AFB; Steve Drinan and Kilby “Killer” Gray at Ft Detrick for being mentors and sounding boards for this research. I am, also, indebted to Rich Prout, Captain Richard Zavadil and the medical logisticians at the Logistics Systems Support Branch who spent their valuable time providing data for this research project.

Christopher J. Estridge

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MATERIAL MANAGEMENT OF MEDICAL-SURGICAL ITEMS AT MILITARY HEALTHCARE FACILITIES

I. Introduction

Supply chain management techniques and innovation within the healthcare arena has increasingly become more and more important as the cost of healthcare has risen within the United States. In the 1970's and 1980's, the costs of healthcare continually surpassed inflation increasing from 6.1% of the gross domestic product (GDP) to almost 11% (Wilson, Cunningham, and Westbrook, 1992). Fast forward to the 21st century and the trend has continued. National health spending is forecasted to outpace GDP growth each year during the next decade. Healthcare expenditures are expected to rise from 16 percent of GDP in 2004 to 20 percent in 2015 (Borger et al, 2006).

One way to decrease the total cost of supplies and the supply chain itself is through choosing an optimal inventory policy that provides the lowest total relevant cost while still providing an acceptable service level to the end customer. In addition to lowest relevant cost as determined by quantitative metrics, qualitative factors should be considered to ensure the organization can support the inventory policy.

A stockless material management inventory policy is one option when choosing an appropriate policy to implement. Stockless inventory policies have been shown to provide multiple benefits after implementation. Some of these benefits cited in literature include inventory reduction, operating expense savings, space savings, inventory line item reduction, increased fill rates, and most importantly, labor savings. Stockless

inventory policies incur additional costs through distributor surcharges that must be offset by the benefits listed above in order to be feasible.

The Air Force Medical Service (AFMS) has pursued a strategy to decrease medical material inventory levels for many years with the belief that decreased inventories translated to lower total costs by decreasing the amount of excess and expired items, with the added benefit of lower personnel costs in managing less inventory. This pursuit of a "stockless" system has decreased inventories carried at each facility and may have only decreased labor costs during the required annual count of inventory on-hand.

This study explored three inventory policies utilizing past purchasing and workload data from 58 facilities to determine whether alternate inventory policies can lower the total cost. Within the AFMS and medical logistics, there is a need to standardize as many procedures as possible to ensure efficient and effective operations at each facility. Standardized practices maintain continuity amongst a fluid and mobile workforce. At the same time, flexibility is required because of the large spectrum of healthcare facilities within the AFMS. Inpatient facilities and small outpatient facilities are different in many ways and may require different management practices to include different inventory management policies for optimal performance. The research also determined whether the low-cost inventory solution could be predicted based on facility size, workload, or volume.

The three inventory policies evaluated included a days of stock policy or (s,S) system. This policy is the current policy utilized by the AFMS inventory management system, Defense Medical Standard Support, and is referred to as the DMLSS policy throughout the rest of the paper. The second policy evaluated was a traditional economic

order quantity (EOQ) policy or (Q,s) system. The third and final policy was a stockless policy, incorporating costs as outlined in the current prime vendor (PV) contract. Stockless material management in the context of this paper refers to the supplier providing a pick-and-pack delivery service such that the hospital virtually eliminates its warehouse and subsequent inventory. Products are delivered in bins tailored either to a requisition or cart-exchange replenishment (Kim and Schniederjans, 1993).

The AFMS purchases the majority of its medical-surgical products from the Defense Supply Center-Philadelphia (DSCP) PV contract which is utilized by all branches of the Department of Defense (DoD). The PV contract as written by the DSCP contracting officers provides common services to all DoD medical facilities and includes customization options that each using facility can elect to add. Common requirements to all facilities include: minimum monthly fill rates (90%), shelf-life requirements, electronic system requirements, and daily deliveries. Optional services that can be selected at either a discounted distribution charge or increased distribution charge include: less frequent deliveries, low unit of measure option, stockless service, wound closure management system, custom palletization, storage space distribution fee offset, full-time on-site customer service representation, PV-supplied on-site materiel manager, and PV product standardization assistance service. There are two primary PV contractors. Each facility is assigned a PV contractor based on the region of the United States in which they are located.

II. Literature Review

The strategic and operational importance of hospital supply chain management is evident when anywhere from 20 to 40 percent of a typical hospital's operating budget is consumed by supply costs (McKone-Sweet et al, 2005). Supply chain costs in healthcare are the second largest cost behind labor (Belkoski, 2008). Supply chain management in other industries, like those of grocery stores or retailers, is much more successful than in hospitals primarily because there is a greater acceptance of the need for supply chain excellence (Burt, 2006). Considerable improvements have been made throughout the supply chain in many industries, but there has been limited success in making system-wide supply chain improvements in the healthcare industry (McKone-Sweet et al, 2005). Other industries and corporations such as Wal-Mart are more organized and more willing to accept and adopt new technological innovations quickly (Burt, 2006). Lawton Burns in the book, The Health Care Value Chain, states that while health care product manufactures operate global businesses; health care providers typically do not. In support of this view, industry observers suggest that health care supply chain characteristics and practices resemble those of industry from the 1960's and 1970's (Burns, 2002). There are however, challenges within the healthcare industry not present in other industries. The obstacles to effective supply chain management in healthcare include (McKone-Sweet et al, 2005):

- Constantly evolving technology resulting in short product life cycles and high cost for physician preference items
- Difficulty in predicting frequency, duration and primary diagnosis for patient visits and the associated product requirements

- Lack of standardized nomenclature/coding for healthcare products and commodities
- Lack of capital to build a sophisticated information technology infrastructure to support supply chain management efforts
- Inadequate business education and supply chain management capabilities among hospital-based buyers

As stated above, stockless refers to the supplier providing a pick-and-pack delivery service so that the hospital virtually eliminates its warehouse and large on-hand stock of inventory. The goal is to eliminate inventory completely in the warehouse, shifting some of the materials management function up the supply chain (Wilson et al, 1992). The prime vendor then charges for labor costs and adds a margin for overhead and profit. Generally, stockless systems add an additional 5 to 8 percent to the cost of supplies purchased (Perrin, 1994). Table 1, below provides a descriptive comparison between traditional and stockless material management systems.

Table 1. Traditional vs. Stockless Comparison (Kim and Schniederjans, 1993)

Variable	Traditional	Stockless
Delivery Method	Bulk	Pick-and-Pack
Delivery Frequency	1-2/week	Daily
Fill Rates	90-95%	98%+
Number of Suppliers	35+	1-2
Storeroom Size	6,000 SF	300 SF
Inventory	6-8 weeks	1-3 days
Central Distribution	Full scale	Min staff
FTE	31	13
Clinical Staff	Significant	None
Receiving Process	Receive/Verify	Sampling
Delivery Pattern	Bulk store	Each user

Stockless material management was the hospital supply chain solution when it was promoted in the late 1980's and early 1990's (Marino, 1998). The practice of stockless eventually reached 10 percent of healthcare institutions in the US, but by the late 1990's, it became clear that stockless agreements were running out of steam (Rivard-Royer et al, 2002). The principal promoters of the practice, the medical supply distributors, began questioning the notion of implementing stockless delivery across the board. Instead, they turned to seeking an optimal balance between their efforts expended in hospital replenishment and the hospitals' inventory savings (Rivard-Royer, et al, 2002).

The stockless method requires continuous flow of information between the point of use and the supplier in order to obtain visibility of demand. This method shifts the institution-distributor interface, moving it closer to the point of use (Rivard-Royer, et al, 2002).

Kim et al, 1993, found that implementing a stockless material management system in a hospital that currently operates a traditional material management system would significantly improve the effectiveness of the operation. Their final conclusion was that regardless of the more abundant results in favor of stockless systems, the results could not be used to universally say that a stockless system is best for all hospitals. Advantages of stockless material management systems per Wilson, Cunningham, and Westbrook (1992) include:

- Reducing costs of inventory
- Eliminating the costs of running a warehouse
- Reducing hospital-assumed costs of obsolescence

- Achieving economies of purchasing and materials management

The extant literature contains multiple positive examples of implementation of stockless materials management systems. Yet, little if any details the failure of a stockless implementation at healthcare facilities. Hospitals who have implemented a stockless material management system have seen quick benefits as they transferred the delivery and storage requirements to their distributors, including reduction in full-time equivalents (FTEs) and cash flow from inventory reductions (Marino, 1998). Two specific examples of direct savings via a stockless system are Vanderbilt University hospital, Nashville, Tennessee and St. Luke's Episcopal Hospital in Houston, Texas. Their improvements are listed in Table 2.

Table 2. Stockless System Benefits (Nathan and Trinkhaus, 1996)

Benefits	Vanderbilt	St. Luke's Episcopal
Inventory Reduction	$2.2 million	$1.3 million
Operating Expense Savings	$750,000	$1 million
Space Savings	29,999 SF	9,000 SF
Inventory Line Item Reduction	From 3,000 < 100	From 1,100 < 100
Fill Rates	99%+	99%+

An additional case study found that after implementing a stockless program, two hospitals reduced their on-hand inventory by more than 70 percent, representing savings in excess of $1 million in one case and $600,000 in the other (Rivard-Royer et al, 2002). The author also notes that a reduction in the workload of both materials management department and patient care staff needed for point-of-use replenishment following the adoption of stockless distribution. It has been noted that staff reduction is one of the most significant sources of cost savings since it is a recurrent savings, not a one-time savings like inventory reduction (Rivard-Royer et al, 2002). Arthur Anderson & Co has

found that institutions using the stockless method have reduced their full-time equivalents by 45 percent, compared to conventional methods (Rivard-Royer et al, 2002).

A stockless inventory management system is not a one-size-fits-all solution. There are factors that are important to potential success. They include: a good materials management information system capable of electronic commerce, percentage of items going through the stockless system versus the percentage delivered outside the stockless distribution system, proximity to the distributor, and adequate contingency plans (Cys, 2001). This research attempts to fill a gap in current literature by providing a quantitative tool to assist senior leaders and managers with the decision to implement a stockless inventory system.

The AFMS is a good test bed for this study for several reasons. First, inventory purchasing data and facility workload data is available from multiple facilities for multiple years. Second, AFMS facilities cover a wide spectrum in size, ranging from very small outpatient clinics to large inpatient medical centers. Finally, AFMS facilities and medical logistics are very similar to private sector facilities. In regards to healthcare, standards of care do not differ and accreditations through agencies like Joint Commisson on Accreditation of Healthcare Organizations do not differ. Medical logistics performs functions much like the private sector and has even modeled its PV contracts to mirror the contracts and agreements in place in the private sector.

Research Questions

The specific research questions addressed that will fill the gap in literature include:

- Can inventory practices be standardized within a large organization by using facility workload and purchasing data?
- Can a least-cost inventory solution be predicted based on non-inventory/purchasing data such as facility size, workload, or volume?

III. Methodology

Two fiscal years of purchasing data for 58 facilities located within the continental United States was obtained from the Air Force Medical Operations Agency (AFMOA), Ft Detrick, Maryland. The data only consisted of purchases from the Medical-Surgical PV through the DSCP PV contract. Facility sizes ranged from small outpatient healthcare facilities to a 200-bed medical center. Additional facility data obtained for the same two fiscal years included: relative value units (RVUs), relative weighted products (RWPs), admissions and dispositions, number of beds, occupied bed days, enrollee population, material management personnel strength and facility personnel strength. RVUs are used by the Military Health System as a measure of provider productivity in terms of volume. RVUs are an indicator of intensity of outpatient services provided. RWPs are essentially the inpatient equivalent of RVUs. Both RWPs and RVUs encapsulate the complexity and volume of patient visits and workload (Fulton et al, 2007).

The PV purchasing data was used to determine total cost for each facility using three different inventory policies. The three policies and methods of computation are explained below.

(s,S) System – The DMLSS Policy

The first policy was the existing policy within the current system utilized by the DoD for inventory management. This policy, labeled “DMLSS”, utilized a formula similar to a days of stock calculation. Information on how the system works and calculates levels and reorder points can be found in Air Force Manual 41-216, *Defense*

Medical Logistics Standard Support (DMLSS) Users Manual. The following equations are central in determining the applicable reorder point and order up to level.

- Reorder Point Percentage (ROPP)
  - $ROPP = \frac{Pipeline\ \ Time\ + Safety\ \ Level}{Pipeline\ \ Time\ + EOQ + Safety\ \ Level} \times 100$
- Reorder Point (s)
  - $ROP = Reorder\ Point\ Percentage \times Stock\ Control\ Level$
- Stock Control Level or Order up to level (S)
  - $SCL = (EOQ + Safety\ Level + PLT) * Daily\ Demand\ Rate$

The numbers for both EOQ and Safety Level are provided from a table from AFM 41-216 which is built into the DMLSS system. The default table in included below at Table 3. These values can be changed by each end user at their respective facility and is source of supply specific. For each item ordered, a total annual cost was calculated and then summed to obtain the total annual cost for the DMLSS policy.

Table 3. DMLSS EOQ and Safety Level Default Values

Projected Annual Sales	< 3 Months History		3-9 Months History		≥ 10 Months History	
	OPR Level (Days)	Safety Level (Days)	OPR Level (Days)	Safety Level (Days)	OPR Level (Days)	Safety Level (Days)
0 - 99.99	0	0	42	7	85	7
> 100 - 499.99	0	0	28	7	57	7
> 500 - 999.99	0	0	21	7	42	8
> 1000 - 2499.99	0	0	10	8	21	10
> 2500	0	0	7	10	14	10

(Q,s) System – EOQ Policy

The second policy utilized was a traditional EOQ policy. The EOQ for each item with demand during the applicable fiscal year was determined utilizing the EOQ equation:

$$EOQ = \sqrt{\frac{2AD}{vr}}$$

where A is order cost, D is annual demand, v is unit variable cost of the item, and r is the carrying cost. The safety level was set at P2 = 0.8 where P2 is a specified fraction of demand to be satisfied routinely from the shelf (Silver et al, 1998). Eighty percent was selected because an analysis of the current fill rates for medical-surgical PV items across the Air Force was around 80%. Thus, the EOQ policy would be consistent with current expected fill rates in DMLSS. Some facilities had obtained higher fill rates and some lower. The safety stock (SS) for each individual item was determined from the following equation:

$$SS = k\sigma_L$$

where k is the safety factor, and σ_L is the standard deviation of the errors of total demand over the replenishment lead time. After the EOQ and safety stock calculations were completed, the total annual cost was determined for each item and then summed to obtain the total annual cost for the policy.

Stockless System

The third and final policy utilized was a stockless policy based on the terms and conditions of the existing PV contract. The stockless service offered by the PV contractors provides that the contractor will on a daily basis: inventory the stock sites, compose the order, obtain government authorization for the order, provided notification on material not available within two hours, deliver and restock material to the site within 24 hours of order receipt, provide priced packing lists prior to restocking, and maintain a fill rate of 99%. The PV charges a percentage mark-up on each item purchased if the

stockless service is chosen by the facility. The percentage mark-up ranges from just over 7% to more than 200% and is based on the dollar value of projected annual sales at the facility.

The stockless policy was a simple calculation of multiplying the cost of the item by the applicable surcharge levied by the PV based on annual dollar sales volume. Each item was summed to obtain the annual cost of the stockless system. Ordering costs were added to obtain total annual cost for comparison to the other two policies described above. We estimated 260 orders per year would be placed with the PV under the stockless system.

In addition to the total annual cost of supplies calculated for each policy, labor costs were added as well. Labor costs were set based on number of material management personnel at each facility and then multiplied by an average cost per person identified below. The stockless system assumed a 20% medical material labor reduction at each facility. Labor cost reductions were the only quantifiable benefit built into the stockless policy. The reason is that labor cost reductions are a recurring benefit that has lasting impact unlike a one-time savings of capital by reducing inventory. For each policy the following constants were used in the calculations:

- Ordering Cost: $4.50 (System default value)
- Holding Cost: 25% (System default value)
- Labor: $49,741/person (Average Pay, medical material technician, 6 years experience)
- Stockless Savings: 20% labor reduction

A simple scatter plot was used to plot the least cost policy based on total facility workload. Facility workload was defined as RVUs plus RWPs.

Analysis of Covariance (ANCOVA), a procedure where "the dependent variable is adjusted statistically to remove the effects of the portion of uncontrolled variation represented by the covariate" (Lomax, 2001), was used to identify relevant facility characteristics that may predict which inventory policy is the least costly and most useful.

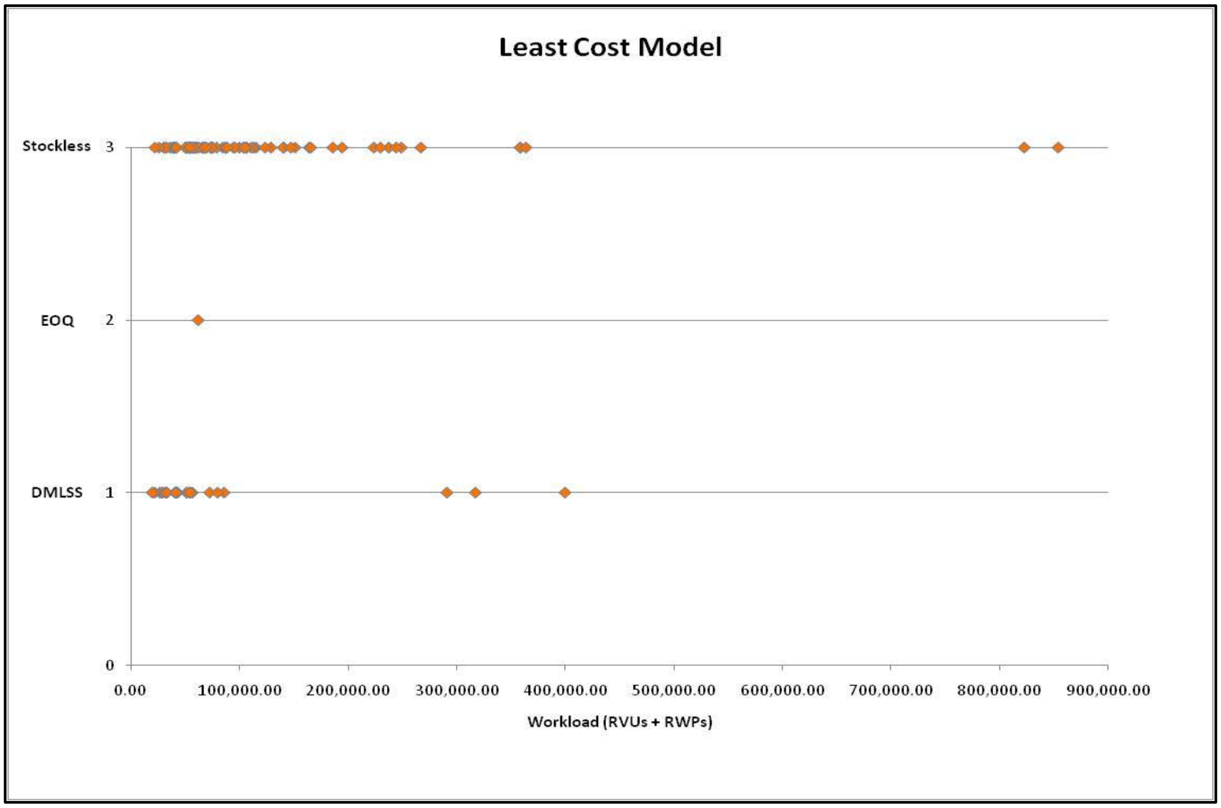
Finally, total cost for the DMLSS policy and stockless policy were set equal and breakeven percentages were determined for each data point. The breakeven percentages for each facility were then plotted against their workload indicator and regression analysis was used to predict when a stockless inventory management policy would be useful.

In the next section, we present the results of our analysis and summarize our findings.

IV. Results

The following scatter plot (Figure 1) plots the least cost policy for each facility versus facility workload.

Figure 1. Least Cost Policy vs. Workload



This initial graphical display of the raw data provides some important initial information. First, given the current structure of the DSCP PV contracts, there is a strong lean to favoring the stockless policy given the cost and labor assumptions that have been stated previously. Second, it appears that only the very small facilities (defined by total workload measure of RVUs + RWPs) may have an advantage of using the DMLSS policy. From this simple scatter plot, it appears that all other facilities have the lowest total cost by utilizing the stockless inventory management policy as defined in the PV

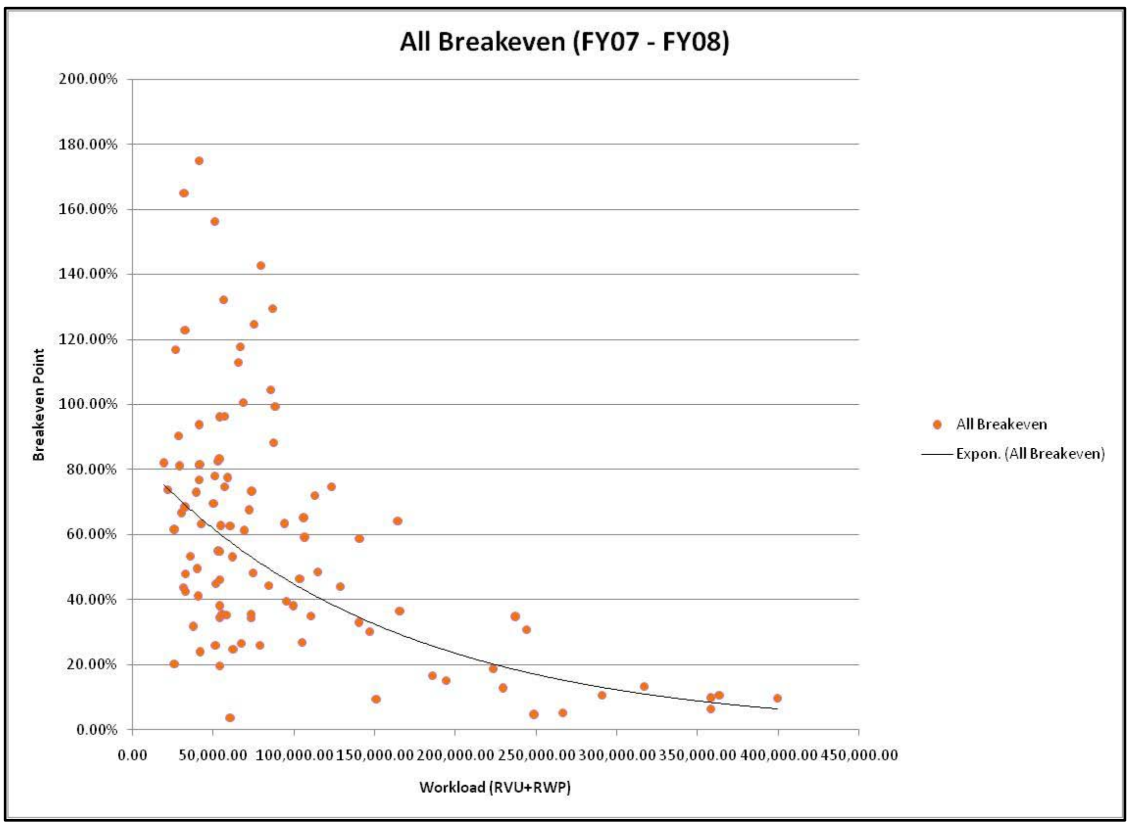
contract. The major reason for these initial results and output is the varying percentage surcharges for a stockless policy levied by the PVs. Smaller facilities in some cases pay a much higher surcharge to implement and maintain a stockless inventory system. These higher additional costs outweigh the benefits of reduced labor costs and leave the DMLSS or EOQ policy as lower cost alternatives.

Analysis of Covariance produced results that were both expected and unexpected. It was found that there is no significant difference between any of the three inventory policies with an F test statistic of 0.073 (p-value > 0.20). This was surprising given the results shown in Figure 1. Considering that the DMLSS policy is a days of stock policy which is equivalent to an EOQ policy converted to days, the fact that those two policiess are not significantly different is logical. The DMLSS system conversion to days of stock is not a textbook calculation and has unique nuances, so to demonstrate that it is not significantly different from the EOQ policy is useful. There was also no significant difference between the two existing PV contractors with an F test statistic of 1.441 (p-value > 0.20). This was also surprising given both the results shown in Figure 1 and given that the two PVs charge very different surcharge percentages.

Finally, the total cost of both the DMLSS and Stockless policies were set equal and then used to determine the breakeven percentage surcharge that could be charged by a contractor assuming a 20% reduction in material handling personnel. This provided a new data point at which the facility could choose to use either the DMLSS policy or the Stockless policy and have the same total annual cost. At this new data point, the facility would be neutral to which policy they utilized. Figure 2 below shows the plot of these new data points against facility workload data.

The plot shows a couple of things of importance at first glance. Smaller facilities, defined by less workload, have opportunities for large gains by implementing a stockless inventory management system. Their breakeven percentages are much greater than larger facilities. The second noticeable item from Figure 2 is the general downward sloping trend. As facility workload measures increase, the breakeven percentage between a DMLSS system and a stockless system decrease. There is however, a large spread and variation among the smaller facilities in terms of their breakeven percentage. As the facility "size" increases, the variability of the breakeven percentage decreases.

Figure 2. Stockless Breakeven Point



The new data points created through the breakeven analysis allowed for the use of regression analysis to determine what variables can predict when to use a stockless inventory management system dependent upon vendor surcharges.

In order to achieve linearity and not violate the assumptions of normality and equal variances, the natural log was taken of the dependent variable (Breakeven Point). Utilizing the natural log of the breakeven percentage as the dependent variable and workload as the independent variable, regression analysis produced a regression equation and adjusted R^2 of:

$$Y = -0.3354 - 0.000004(x)$$

$$R^2 = 41.5\% \qquad R^2(Adj) = 40.9\%$$

where *Y* is the natural log of the breakeven percentage, and *x* is RVUs plus RWPs. The plot of residuals passes the test of normality using the Kolmogorov-Smirnov test of normality. Results were significant with an F test statistic of 69.59 (p-value < 0.000).

The breakeven analysis as shown in figure 2 shows a non-linear relationship between the percentage surcharge and workload. The non-linear relationship provided the justification to consider a polynomial regression, introducing x^2 as another input into the regression. The adjusted R^2 improved by over ten percentage points and produced the following regression equation:

$$Y = -0.01617 - 0.008297(x) + 0.000007(x)^2$$

$$R^2 = 52.0\% \quad R^2(Adj) = 51.0\%$$

where *Y* is the natural log of the breakeven percentage and *x* is (RVUs plus RWPs)/1000. The plot of residuals passes the Kolmogorov-Smirnov test of normality. Results were significant with an F test statistic of 52.45 (p-value < 0.000).

While the above results provided a regression equation that could be used to find a facility's indifference point to a stockless inventory management policy or DMLSS policy, we decided to remove all non-inpatient facilities from the regression and recalculate the equation. The reason for this decision is that DoD healthcare facilities have characteristics that do not mirror civilian facilities. Many of the smaller, outpatient clinics within the DoD provide services more in line with private physician practices but with "extras" built in. For example, most DoD facilities will operate a pharmacy and lab which isn't the standard practice in the private sector for similar sized clinics.

Removing all non-inpatient facilities from the data set left 16 data points that most aligned with the private sector, though some differences do still exist. By also removing all non-inpatient facilities, multiple predictor variables indicative of inpatient facilities not used in the previous regression were able to be utilized. Multiple regression analysis was used to analyze the relationship between the breakeven percentage and several independent variables. The independent variables included: RWPs, admissions, bed days, and number of beds. The natural log was still taken of the dependent variable, the breakeven percentage, to normalize the data.

The regression equation providing the best fit to the data was:

$$Y = -0.818 - 0.000612(x_1) - 0.000718(x_2) + 0.00104(x_3) - 0.187(x_4)$$

$$R^2 = 67.3\%, \quad R^2(Adj) = 55.4\%$$

where Y is the natural log of the breakeven percentage, x_1 is RWPs, x_2 is admissions, x_3 is number of bed days used during the year, and x_4 is the number of beds in the facility. The plot of residuals passes the Kolmogorov-Smirnov test of normality. The model was statistically significant with an F test statistic of 5.67 (p-value < 0.01). Table 4 provides

the coefficients, t-statistics, and significance level for each predictor variable. This model however had problems with multicollinearity between the predictor variables as shown in table 5 below.

Table 4. Regression Model

LN Breakeven	ß	t
RWPs (x_1)	-0.0006124	-2.18 *
Admissions (x_2)	-0.0007182	-3.35 ***
Bed Days (x_3)	0.0010395	2.86 **
Number of Beds (x_4)	-0.18704	-2.20 **
Constant	-0.8177	-2.82 **
N		16
R^2		0.67
F		5.667 ***

* < 0.1
** < 0.05
*** < 0.01

Table 5. Pearson Correlation Coefficients

	Log_Break	RWPs	Admissions	Bed Days	Bed Status
1 Log_Break	1.000				
2 RWPs	-0.363 *	1.000			
3 Admissions	-0.395 *	0.992 **	1.000		
4 Bed Days	-0.330	0.996 **	0.994 **	1.000	
5 Bed Status	-0.331	0.995 **	0.993 **	1.000 **	1.000

* Correlation is significant at the 0.10 level
** Correlation is significant at the 0.01 level

The problem of multicollinearity was handled by removing all predictor variables and focusing on only one variable in a simple regression model. The predictor variable that provided the best fit to the data was RWPs using a quadratic equation, again because of the non-linear relationship between the breakeven percentage and RWPs. RWPs were

divided by 1000 to create a more manageable regression equation. The regression equation that provided the best fit was:

$$Y = -1.348 - 0.3735(x) + 0.02056(x^2)$$

$$R^2 = 48.2\%, \quad R^2(Adj) = 40.2\%$$

where Y is the natural log of the breakeven percentage and x is RWPs divided by 1000 for the facility.

The plot of residuals passes the Kolmogorov-Smirnov test of normality. The model was statistically significant with an F test statistic of 6.04 (p-value < 0.05).

V. Conclusions

Limitations and Future Research

There are several limitations when using AFMS data and applying the resulting analysis to non-DoD healthcare facilities. The first is that the AFMS has a War Reserve Materiel (WRM) requirement that private sector healthcare facilities do not. WRM is a go-to-war medical capability that is maintained in a ready to deploy state. Maintaining WRM requires both personnel and financial resources that are not required of the private sector.

Second, AFMS facilities provide some services that would be obtained via other providers or referrals in the private sector. For instance, most AFMS facilities have dental clinics attached to them. Many AFMS facilities also have full service pharmacies, lab support, and physical therapy. These services are found within most AFMS facilities regardless of size. By having these additional services, manpower is increased within the medical material department. This increased manpower is then factored into the stockless benefits above, possibly distorting the overall savings provided by a medical-surgical stockless inventory system.

Finally, although breakeven or indifference points can be predicted for stockless inventory systems, stockless services may not be offered to small facilities. Many vendors may not offer stockless inventory options to small facilities because it simply may not be profitable to the vendor. In the case of the DoD, stockless services are required to be offered to all facilities as part of the PV contract.

This research can be made stronger by several means. First, adding more years of data after it is available from the AFMS. In addition, adding private sector data to the

existing data could enhance and strengthen the predictive value of the regression analysis. Second, utilizing more exact labor rates for each facility will add a layer of granularity not captured by this research. Finally, ensuring accurate measures of ordering and holding cost will guarantee the most accurate total cost for each inventory policy. The current figures used for this research were default values provided in the DMLSS system which may or may not be accurate and truly representative of the actual costs.

Managerial Implications and Conclusions

Our findings indicate that as facility size and workload increase, the percentage charged by a vendor for stockless inventory management implementation and sustainment must decrease for the facility to breakeven. The results of this research filled a gap in the current literature by providing a quantitative method to approximate the least cost inventory policy for healthcare facilities regardless of size. We improved upon our first model by removing all non-inpatient facilities from the data, introducing additional predictor variables, and running linear regression. This final model is a good predictor of when a facility should consider a stockless inventory system based on facility size and workload.

Before implementing a stockless inventory management system, managers and senior leaders should consider not only these models presented, but other qualitative factors presented in the literature review. Factors to consider include: capability of the materials information system and current vendor, percentage of items to be converted to stockless system, proximity to the distributor, and adequate contingency plans (Cys, 2001).

Overall, this model is a good start to creating quantitative tools to determine least cost and optimal material management inventory systems. Further development and the use of other predictor variables not available for this research may create a stronger product to be utilized by material managers and senior leaders.

Appendix A: Story Board

Appendix B: Slide Presentation

Air Force Institute of Technology

Material Management at Military Healthcare Facilities

Maj Chris Estridge

Lt Col Pamela Donovan

U.S. AIR FORCE

Educating the World's Best Air Force

Overview

- Theory/Background
- Research Question
- Models and Assumptions
- Method
- Results

Theory

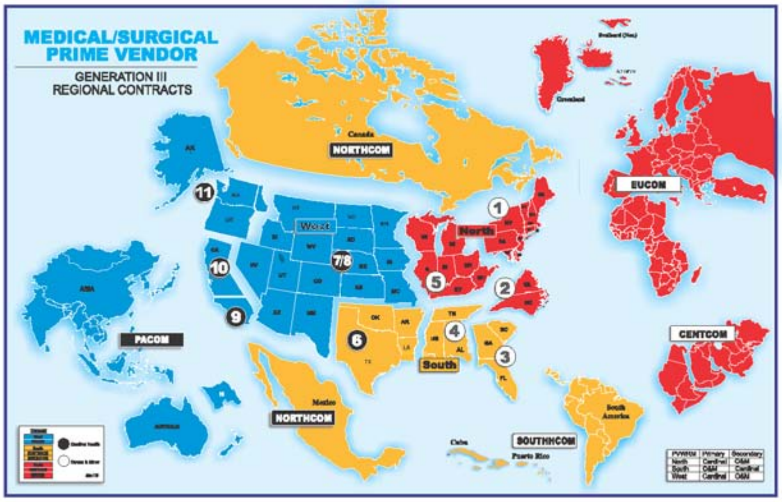
- Increased costs a concern
- Medical supply expense 20% of operating budget (Belkoski, 2008)
- Stockless Benefits
  - Can significantly improve the effectiveness of the operation (Kim and Schniederjans, 1993).
  - Reduce FTEs by 45% compared to conventional methods (Arthur Anderson & Co., 1990)
- No one-size-fits-all solution (Marino, 1998)

Air Force Medical Operations Agency – Med Log Division

- Relook at proper inventory levels at Air Force facilities

- Old – “How do I get the dope to the doc”
- New – “How much does it cost to get it there and is there a generic”

Medical-Surgical Prime Vendor (PVM) Regions



Defense Medical Logistics Standard Support (DMLSS)

Research Question

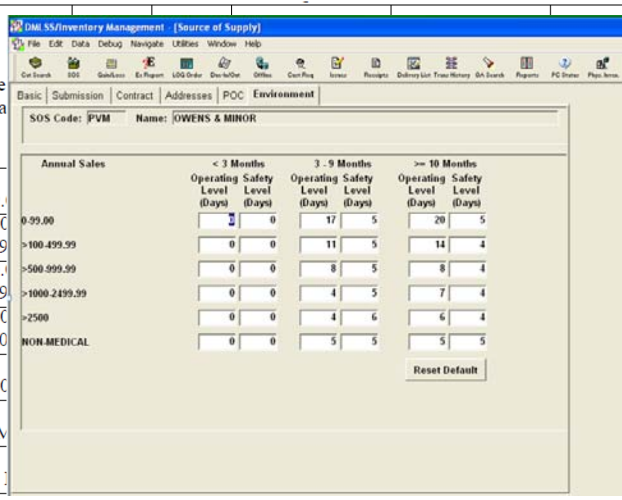
- Can inventory practices be standardized within a large organization by using facility workload and purchasing data?

DMLSS Model

- (s,S) System
  - Reorder point for each item
  - Order up to level
- Daily Review
- Days of Stock

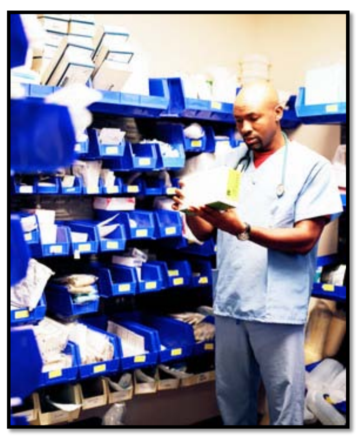
Days of Stock

Proje Annua	Months
	Safety Level (Days)
0 - 99.	7
>100.0 499.99	7
> 500. 999.99	8
> 1000 2499.0	10
> 2500	10
Non-M	7
Spare	15



Alternative 1 – EOQ Model

- (s,Q) System
  - Reorder point for each item
  - Fixed quantity order
- Daily Review



Alternative 2 – Stockless Model

- Based on current PVM contract utilized by the Military Health Service
- Charges range from 7.6% - 201.3% depending on sales

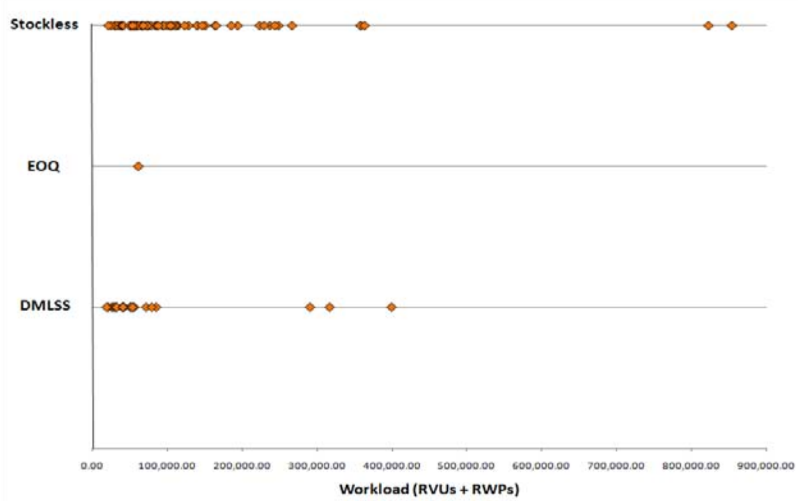
Assumptions

- 20% reduction in medical material manpower for stockless method
  - Literature shows savings as high as 45%
- Order cost – $4.50
- Carrying Cost – 25%

Method

- Only CONUS bases utilized (58 facilities)
- Four years of PVM data received
- TRC for each model
- ANCOVA utilized to identify relevant facility characteristics

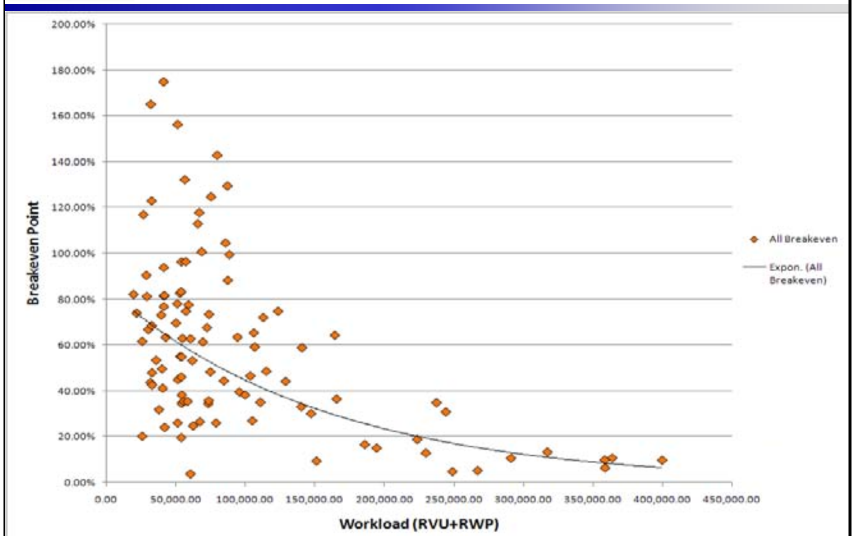
Least Cost Model



ANCOVA Results

- No statistical difference between any of the methods
  - Days of Stock = EOQ = Stockless
- No statistical difference between contractors

Breakeven or Indifference



First Model – All Facilities

$$LogBreakeven = -0.01617 - 0.008297(x) + 0.000007(x)^2$$

Model Summary[b]

R	R Square	Adjusted R Square
0.721[a]	0.520	0.510

a. Predictors: (Constant), Workload, Workload^2

b. Dependent Variable: Log_Break

ANOVA[b]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	30.631	2	15.315	52.450	0.000[a]
Error	28.324	97	0.292		
Total	58.954	99			

a. Predictors: (Constant), Workload, Workload^2

b. Dependent Variable: Log_Break

Second Model – Inpatient Only

$$\begin{aligned} Log\ Breakeven &= -0.818 - 0.000612(RWPs) - 0.000718(Admissions) \\ &+ 0.00104(Bed\ Days) - 0.187(Number\ of\ Beds) \end{aligned}$$

Model Summary[b]

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.821[a]	0.673	0.554	0.398

a. Predictors: (Constant), Bed Status, Admissions, rwps, Bed Days

b. Dependent Variable: Log_Break

Coefficients

Predictor	Coef	SE Coef	T	P
Constant	-0.8177	0.2903	-2.82	0.017**
Bed Days	0.0010395	0.0003629	2.86	0.015**
Bed Status	-0.18704	0.08489	-2.20	0.05**
RWPs	[illegible]	0.0002804	-2.18	0.052*
Admissions	[illegible]	0.0002142	-3.35	0.006***

* Significant at $\alpha = 0.1$

** Significant at $\alpha = 0.05$

*** Significant at $\alpha = 0.01$

Multicollinearity

ANOVA[b]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.591	4	0.898	5.667	0.010[a]
Residual	1.742	11	0.158		
Total	5.333	15			

a. Predictors: (Constant), Bed Status, Admissions, rwps, Bed Days

b. Dependent Variable: Log_Break

Final Model – Inpatient Only

$$Y = -1.348 - 0.3735(x) + 0.02056(x^2)$$

$$R^2 = 48.2\%, \quad R^2(Adj) = 40.2\%$$

- F-Statistic: 6.04 (p-value < 0.05)

Where:

- *Y* = Natural Log of the Breakeven Percentage
- *x* = RWPs/1000

Conclusions

- No one-size-fits-all solution
- Need multiple tools to determine best policy

Questions?

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Appendix C: Blue Dart

Controlling Cost of Healthcare Starts with the Supply Chain

Christopher J. Estridge, Major, USAF, MSC
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Supply chain management techniques and innovation within the healthcare arena has increasingly become more and more important as the cost of healthcare has risen within the United States. The cost of healthcare has continually surpassed inflation since the 1970's and become an ever increasing percentage of the United States' gross domestic product. Supply chain costs are the second largest cost in healthcare, behind only labor costs, which make it a prime target for optimization and reduction.

One way to decrease the total cost of supplies and the supply chain itself is through choosing an optimal inventory policy that provides the lowest total relevant cost while still providing an acceptable service level to the end customer. In addition to lowest relevant cost as determined by quantitative metrics, qualitative factors should be considered to ensure the organization can support the inventory policy.

A stockless material management inventory policy is one option when choosing an appropriate policy to implement. Stockless inventory policies have been shown to provide multiple benefits after implementation. Some of these benefits cited in literature include inventory reduction, operating expense savings, space savings, inventory line item reduction, increased fill rates, and most importantly, labor savings. Stockless inventory policies incur additional costs through distributor surcharges that must be offset by the benefits listed above in order to be feasible.

A recent study, utilizing Air Force healthcare facility data, examined quantitative factors that could be used to predict when a stockless inventory policy would be the least cost method. The study compared the cost of a traditional inventory policy such as economic order quantity, or days of stock to the cost and projected benefits of a stockless policy. The study assumed a twenty percent reduction in medical material personnel labor costs as the only cost savings to offset the distributor surcharge.

Initial findings of the study found that as the size of the facility, defined as relative value units plus relative weighted products, increases, the surcharge levied by the distributor must decrease in order for a stockless inventory policy to be viable. It was also observed that as facility size increased, the variability in the data decreased.

While the initial results of the study provided a model that was deemed statistically significant, all non-inpatient data points were removed from the data set and further analysis was performed. The reason for the data extrapolation was to produce a model that mirrored a private sector healthcare facility that was most likely to consider a stockless inventory policy.

Removing all non-inpatient facilities from the data set allowed multiple predictor variables to be analyzed in the regression not previously utilized. The variables used were relative weighted products (RWPs), admissions, bed days, and number of beds. The most useful predictor variable was found to be RWPs for inpatient facilities. The model provides a decision maker with a breakeven or indifference point where a traditional inventory policy and stockless inventory policy are equal. The model was determined to be statistically significant and is shown below. The coefficient of determination or R^2 for the model was determined to be 48.2%.

$$LN(Breakeven) = -1.348 - 0.3735(RWPs/1000) + 0.02056(RWPs/1000)^2$$

Stockless inventory policies are not a one-size-fits-all solution. There are qualitative factors that are important to potential success or failure. Potential implementation should only be considered if an adequate materials management information system capable of electronic commerce is available. The percentage of items going through the stockless system versus the percentage delivered outside the stockless distribution system should be considered. The facility's proximity to the distributor for quick deliveries is an important component for consideration. Finally, any healthcare facility that determines a stockless inventory policy is optimal should ensure both they and their distributor have adequate contingency plans in place to account for possible disruptions in service.

Short of eliminating physicians and other healthcare providers, controlling the rising cost of healthcare falls on the supply chain and material management leaders. Utilizing both quantitative and qualitative information available in literature can point an organization to an optimal inventory policy that can not only reduce total supply costs but that may also reduce labor costs at the same time.

Major Chris Estridge is a Masters IDE student at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio in the Department of Operational Sciences. Following graduation, Maj Estridge will be the Supply Chain Support and Optimization Branch Chief at the Air Force Medical Operations Agency, Medical Logistics Division, Fort Detrick, Maryland.

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Vita

Major Estridge graduated from Clemson University, Clemson, South Carolina where he received a Bachelor of Science degree in Health Science in 1996. Upon graduation from Clemson he earned a Masters in Health Administration from the Medical University of South Carolina, Charleston, South Carolina in 1999. He was a direct commission to the Medical Service Corps in 1999.

His first assignment was at Travis AFB, California as a Medical Logistics Intern in April 2000. In January 2001, he was assigned to the 92nd Medical Support Squadron, Fairchild AFB, Washington where he served as the Medical Logistics Flight Commander. Next, he was assigned to Ft Detrick, Maryland as part of the Air Force Medical Logistics Office where he served on the Air Staff for two years. Following his assignment to the Air Staff, Maj Estridge was assigned to the 435th Medical Support Squadron, Ramstein AB, Germany where he served as flight commanders for both Medical Logistics and Medical Readiness. While stationed at Ramstein, he deployed in July 2007 with the U.S. Army to Afghanistan as part of an Embedded Training Team to the Afghanistan National Army.

In June 2008, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will return to the Air Staff at Ft Detrick, Maryland.

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14. ABSTRACT
This research examined whether certain military healthcare facility characteristics could be used as determinants in setting materials management policies. Cost efficiency in the military healthcare system is as important as it is in the civil sector, which has led to an increased emphasis on material management policies and a drive toward stockless inventory practices. The benefits (success) of stockless inventory policies in the civil sector have been mixed. In the early to mid 90's, stockless inventory systems were the end-all solution. They have since faded with many organizations settling on a blend of stockless and traditional inventory practices. Air Force healthcare facilities currently use a Days of Stock inventory policy with defaults set for operating level and safety levels based on source of supply. The material management policies at Air Force healthcare are relatively static with a one-size-fits-all approach, although they vary by size and operation. This study examined the total relevant inventory costs of the (Q,s), (s,S), and stockless inventory policies available in the Defense Supply Center-Philadelphia Medical-Surgical Prime Vendor contract in use at Air Force healthcare facilities located within the continental United States. Further, quantitative approaches analyzed current and past acquisition data to draw conclusions on the best cost minimizing inventory policy based on factors such as number of personnel, number of beds, number of bed days, relative value units, relative weighted products, admissions, and enrolled population. The results show that workload factors such as relative value units and relative weighted products can be used to predict an appropriate least cost inventory policy for individual healthcare facilities.

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